REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
	Technical Papers	

4. TITLE AND SUBTITLE

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Air Force Research Laboratory (AFMC)
AFRL/PRS
5 Pollux Drive
Edwards AFB CA 93524-7048

8. PERFORMING ORGANIZATION REPORT

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Air Force Research Laboratory (AFMC)
AFRL/PRS
5 Pollux Drive
Edwards AFB CA 93524-7048

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

20020828 164

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
					Leilani Richardson
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** *(include area code)*
Unclassified	Unclassified	Unclassified	A		(661) 275-5015

41 items enclosed

NASA 002W

MEMORANDUM FOR PRS (In-House Publication) 03 November 1999

FROM: PROI (TI) (STINFO)

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-ABS-1999-077**
Mead, F., Squires, S., et al., "Flights of a Laser-Powered Lightcraft During Laser Beam Hand-off Experiments" **(Statement A)**

36th AIAA/ASME/SAE/ASEE Joint Propulsion Conference

FLIGHTS OF A LASER-POWERED LIGHTCRAFT DURING LASER BEAM HAND-OFF EXPERIMENTS

Franklin B. Mead, Jr.
Air Force Research Laboratory
Propulsion Directorate
Edwards AFB CA 93524

Stephen Squires, Chris Beairsto, & Mike Thurston
Army Test and Evaluation Command
Applied Technology Test & Simulation Directorate
High Energy Laser System Test Facility (HELSTF)
White Sands Missile Range NM 88002

ABSTRACT

The Lightcraft Technology Demonstrator (LTD)[1] was a laser propelled trans-atmospheric vehicle concept developed at Rensselaer Polytechnic Institute (RPI) for Lawrence Livermore National Laboratory and the SDIO Laser Propulsion program in the late 1980's. This laser launch concept was envisioned to employ a 100 MW-class ground-based laser to transmit power directly to the Lightcraft in flight. An advanced, combined-cycle engine would propel a 120 kg (265 lb) dry mass, 1.4 m (4.59 ft) diameter LTD, with a mass fraction of 0.5, to orbit. The LTD vehicle would then become an autonomous sensor satellite capable of delivering precise, high quality information typical of today's large orbital platforms.[1] Here, the 1 m diameter afterbody optic served as optical telescope or receiving/transmitting antenna for low power laser or microwave communication systems.

The dominant motivation behind the LTD study was to provide an example of how laser propulsion could reduce, by an order-of-magnitude or more, the production and launch costs of sensor satellites. The 1989 study concluded that a vehicle production cost of $1,000/kg was realizable, and that launch costs must be limited to less than $100/kg for laser propulsion to play a significant role in the future of space transportation. Today, our expectations for the use of laser propulsion technology are slightly less ambitious. We envision the launching of 1 kg (2.2 lb) Laser Lightcraft into a low-earth-orbit (LEO) for less than $500 of electrical power using a 1 MW CO_2 pulsed, electric laser. Production costs of about $3,000 for the 1 kg spacecraft appear reasonable at present. Reference ?

The LTD concept, was, a microsatellite in which the laser propulsion engine and satellite hardware were intimately shared.[1] The forebody aeroshell acted as an external compression surface (i.e., the airbreathing engine inlet). The afterbody had a dual function as a primary receptive optic (parabolic mirror) for the laser beam and as an external expansion surface (plug nozzle) during the laser rocket mode which is used only in space. The primary thrust structure was the annular shroud. The shroud serves as both air inlet and impulsive thrust surface during the airbreathing mode. In the rocket mode, the inlets are closed, and the afterbody and shroud combine to form the rocket thrust chamber and plug ("aerospike-type") nozzle.

The objective of the current vertical flight program is to develop a laser beam "hand-off" technique for future flight tests powered to the edge of space (~30 km), and to extend Lightcraft flights to significantly higher altitudes in the range of 150 to 300 m. The hand-off technique is the method by which the laser light beam is transferred to consecutively larger telescopes during a Lightcraft launch. In other words, the laser light is initially directed through a small diameter telescope at the start of the launch, Then, as the Lightcraft speeds to higher and higher altitudes, the laser light is suddenly shifted, at a prearranged altitude, to a larger diameter telescope. This larger telescope allows the beam to be appropriately focused at the higher altitudes. This laser hand-off will probably occur several times during the actual launch to LEO of a full scale Lightcraft.

A subscale version of the LTD vehicle is being developed by the Air Force Research Laboratory's Propulsion Directorate. This laser-powered Lightcraft, which is being used during the laser hand-off tests, is a 1/10th-scale model of a Laser Lightcraft vehicle concept that is envisioned to launch 1-kg payloads into LEO for less than $500 of electrical power some time in the next 5 to 7 years. The laser hand-off tests were conducted at the High Energy Laser System Test Facility (HELSTF), White Sands Missile Range (WSMR), New Mexico, using the Pulsed Laser Vulnerability Test System (PLVTS) CO_2 electric discharge laser. This laser is a pulsed wave, closed

[1] Myrabo, L.N., "Transatmospheric Laser Propulsion," Final Technical Report, Rensselaer Polytechnic Institute, Prepared under Contract No. 2073803 for Lawrence Livermore National Laboratory and the SDIO Laser Propulsion Program, 30 June 1989.

cycle CO_2 laser with a pulse repetition rate of 1 to 30 pps (selectable), and a variable pulse width of 5 to 30 μs. For the laser hand-off tests, the laser was operated at 25 pps and 18 μs pulse width.. This paper will ~~give~~ discuss laser modifications that were made to improve performance just prior to the flight experiments, their benefits, and the results of the laser hand-off experiments. Details of the Lightcraft performance over altitude and distance from the laser will be presented along with flight details and video footage taken during the outdoor free flight tests.

[redacted]

5-63
-6433

COMBUSTION, ENGINES, & PROPELLANTS

Electric & Ion Propulsion

009,307
DE89017528/GAR PC **A06**/MF **A01**
Lawrence Livermore National Lab., CA.
Transatmospheric Laser Propulsion: Final Report.
L. N. Myrabo. 15 Aug 88, 118p UCRL-21156, CONF-880764-7
Contract W-7405-ENG-48
24. AIAA/ASME/SAE/ASEE joint propulsion conference, Boston, MA, USA, 11-13 Jul 1988.
Portions of this document are illegible in microfiche products.

The detailed description and performance analysis of a 1.4 meter diameter Lightcraft Technology Demonstrator (LTD) is presented. The novel launch system employs a 100 MW-class ground-based laser to transmit power directly to an advanced combined-cycle engine that propels the 120 kg LTD to orbit – with a mass ratio of two. The single-stage-to-orbit (SSTO) LTD machine then becomes an autonomous sensor satellite that can deliver precise, high quality information typical of today's large orbital platforms. The dominant motivation behind this study is to provide an example of how laser propulsion and its low launch costs can induce a comparable order-of-magnitude reduction in sensor satellite packaging costs. The issue is simply one of production technology for future, survivable SSTO aerospace vehicles that intimately share both laser propulsion engine and satellite functional hardware. 12 refs., 31 figs.

Jet & Gas Turbine Engines

009,308
AD-A214 258/6/GAR PC **A10**/MF **A02**
Pratt and Whitney, West Palm Beach, FL. Advanced Engineering Div.
Thermal Mechanical Fatigue of Coated Blade Materials.
Final rept. 1 Aug 84-30 Sep 88.
J. E. Heine, J. R. Warren, and B. A. Cowles. 27 Jun 89, 216p PW/FL/FR-20505, WRDC-TR-89-4027
Contract F33615-84-C-5027

A model capable of predicting thermal mechanical fatigue (TMF) crack initiation and propagation in coated advanced blade materials, with emphasis on crack initiation, was developed and demonstrated. The experimental program included isothermal baseline and TMF tests on one alloy and two coating materials to evaluate the effects of mean stress, frequency, hold peri-

therefore decided to conduct a series of four Workshops addressing the areas critical to Damage Tolerance design of engine parts. The present report includes the papers presented during Workshop II dealing with Defects and Quantitative Materials Behaviour. It also includes the content of the discussions which followed the presentations. Keywords: Endurance general; Fatigue mechanics; Engine disks; Cracks; Gas turbines; Nato; Alloys; Metals; Aircraft engines. (AW)

009,310
AD-A214 448/3/GAR PC **A01**/MF **A01**
Florida State Univ., Tallahassee. Dept. of Mathematics.
Computation of Broadband Mixing Noise from Turbomachinery.
Semiannual progress rept. 1 Mar-31 Aug 89.
C. Tam. Aug 89, 2p
Contract N00014-89-J-1836

Broadband mixing noise are generated by a number of sources inside a turbomachine. The most important sources are the turbulent boundary layers (on the casing walls or on the blades), the turbulent free shear layers (separated flows) and turbulent wakes (from blades). High quality noise data are currently not available. A set of reliable near and far field mixing noise data from the free shear layers of a low speed jet was obtained. Work concentrated on broadband mixing noise theory on free shear flows. One began the theory by adopting the Kappa-Epsilon turbulence modeling equations as the basis. Although at this stage the formalism is the same yet a slightly different interpretation of the physical variables is needed. The averaging process is to be a volume average. On assuming there is a distinct separation of scales between the large turbulence structures and fine scale turbulence a closed set of governing equations can be derived in the usual way by using a volume average. The volume is to be small compared with the large turbulence structures but large compared to the fine scale turbulence. The semi-empirical constants used in turbulence calculation will be adopted. The next stage of work is to develop ways of solving the time dependent equations and to determine the radiated noise intensity and spectrum. (JHD)

009,311
DE89000952/GAR PC **A23**/MF **A01**
Department of Energy, Morgantown, WV. Morgantown Energy Technology Center.
Proceedings of the Annual Coal-Fueled Heat En-

Adv
gran
Prod
Turb
Apr 8
Porti
produ

This
Proje
input
adva
izatic
the f
strate
refs.,

009,
N90-
Natic
Cleve
Adva
Desi
C. L.
NAS/
Prese
1989

A his
techr
velop
sente
furthe
ogies
signif
dema
sion
sente
now
trans
to a c
curre
hanc

009,
N90-
Natio
Cleve
Effec
form
F. M.
1.15:
Previ
at th
Ca.